

Technologies for Aging Societies

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Beyond Pension and Health Care Rationing

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Introduction

It is hardly news to this Plenary of the Commission on Global Aging that the demographic trends of the next few decades will impose unprecedented economic, societal and political pressures on the industrially developed states. We at a Sandia National Laboratories, a U.S. national security laboratory, are particularly conscious of the international security implications of those pressures.

Among the potential security consequences we see are that:

- we and our allies won't be able to pay for pension and health care commitments, let alone find the resources to keep up our military establishments;
- our military will have to compete for people in economies already suffering labor shortages;
- we won't be able to increase our military budgets to meet any new national security threats;
- we won't be able to borrow from each other to finance our deficits;
- discord between young and old will prevent consensus on outward-looking global security policies;
- weakened military potential could mean a less stable world, further slowing economic growth and so making a vicious circle of declining prosperity at home and more conflict abroad

In this Commission, and in other forums addressing the global aging problem, we have seen a good deal of discussion of the budgetary and economic issues surrounding the problem. Much of this discussion centers on the unpalatable choices facing our governments and societies as our population ages. Economists and political analysts explain that we will have to try to balance national budgets by striking some balance among raising retirement ages, reducing pension benefits, rationing health care, and raising taxes.

Unquestionably, some painful national choices lie ahead of the industrialized states. At the same, we believe that the standard economic-political analyses tend to omit grounds for optimism. They do so because they tend to hold *technology* constant—to assume implicitly that the same relationships between population age and economic productivity will persist throughout the aging transition. We argue that introducing technology considerations into the discussion of policy issues opens additional options beyond rationing and taxation.

If the industrial states could greatly increase the productivity of each worker, they could sustain current pension and benefit commitments by producing more goods and services with fewer workers. The elderly (as currently defined) could retire on schedule, while the young would not see their tax *rates* go up.

Today the information revolution is still far from complete, with computing capabilities still rising according to Moore's law, wide band telecommunications just

beginning, and the globalization of the communications network still under way. The industrial and agricultural applications of biotechnology are just getting off the ground. On the horizon, nano-, info-, and biotechnology could bring whole new industries and levels of productivity. Nevertheless, few today would gamble our economic future on sufficient productivity increases over the next 20 or 30 years for the working age population to support the future retired population at today's tax and benefit rates.

This paper argues that technology can enable us to reduce the societal burden of the aging segments of our populations by greatly extending their health and productivity—but only if we can make the appropriate investment choices and social and cultural adaptations.

Various analysts of the aging problem have pointed out that in many countries current notions of the appropriate retirement age can be traced back to Bismarck, who, in 19th-century Germany set 65 as the pensionable age—at a time when male life expectancy was only 55. For various reasons, numerous industrialized societies have structured incentives to induce people to retire at 65 or even younger. Changing these incentives (including cutting back early retirement benefits and reducing penalties on post-retirement earnings) could ameliorate the dependency ratio problem.

On the face of it, it only seems a fair trade: if we get to live longer, we should have to work longer, rather than expect younger taxpayers to finance a 20-year or longer retirement for us. There are, however, problems with this framing of the problem. First, when our working populations were still much larger relatively to our retired populations, it was economically feasible in pay-as-you-go systems (like U.S. Social Security) to finance the long retirements of those lucky enough to live long. Thus we have created an intergenerational bargain with expectations of comparable benefits: we pay now for the elderly, and the next generation pays for us. Changing this expectation—renegotiating the bargain—will be difficult enough.

It is also the case though, that longer life spans have not been fully matched by longer health spans: many of the elderly are, to various degrees, disabled by various forms of disease. They feel not only entitled to rest, but also unable to work. Their disabilities also place additional burdens on society in the form of subsidized medical care. Good health, therefore, is the key to maintaining productivity and the ability to continue workforce participation. Reducing the cost of health care also will be an essential part of reducing the dependency problem. Maintaining good health and preventing disease will be the most cost-effective way of reducing the societal burden imposed by an aging population. For those in whom disease cannot be prevented, new methods of treatment have the potential to reduce severity and costs of diseases.

As we detail the above arguments, we disperse through the paper six vignettes (in boxes) illustrating some of the technologies identified in the text.

Prolonging the Health and Productivity of the Elderly

We find it convenient for analysis to parse the problem of prolonging the health and productivity of the older population into three levels: the societal, the personal-social (or interpersonal), and the organic. These divisions give us a framework for discussing what seem to be the key issues. For each level, we indicate the kinds of changes the problem calls for, plus some technologies that might foster or enable those changes.

Societal Changes¹

Cultural Expectations

At the societal level, nations have evolved cultural expectations about what it means to be “old” and what the appropriate roles are for the elderly. If older citizens are to participate more fully in their societies, cultural expectations will have to change. For example, societies will have to break current equations between “old” and numerical age, and between “old” and “disabled.” For many older people, these equations are already obsolete. This trend should be fostered.

The industrial societies will need to move away from the expectation that nearly everyone “works to retire” and toward the expectation that people will more often make life-long contributions.

At least in the United States, we already see some changes in cultural expectations of the elderly, and, as the “baby-boomers” age, we expect to see more. Communications media can be enablers of such change, with entertainment providing role models and the internet providing broadened opportunities of continuing education, occupational retraining, and tools for maintaining mental acuity. In addition, other technologies (see the vignettes below) for maintaining health, compensating for physical and mental disabilities, and compressing end-of-life morbidity will contribute toward changing everyone’s expectations of what the elderly can do.

Institutions

Cultural expectations frequently find expression in societal institutions that shape the environments in which the elderly function. These institutions include the immediate community, employers, and the health care establishment. Societal institutions, especially governments, promulgate and carry out policies aimed at affecting the health of the overall population (or significant segments of it), i.e. public health.

Community

In today’s urban industrial societies, older citizens tend to be isolated within their communities. Some are warehoused in nursing homes; others form “retirement communities” in segregated living facilities. Those still living at home

¹ In August 2000, the Sandia National Laboratories Advanced Concepts Group held two workshops with health care community professionals that discussed many of the societal and personal-social level topics mentioned here, and this discussion draws heavily on the proceedings of those workshops.

may find that disabilities and lack of mobility keep them from interacting fully with the younger community. These patterns will make less sense as the elderly fraction of the population grows. If they are to be continuing contributors, older people will need to be more fully integrated into mainstream communities and young and old will have to find mutually supportive roles.

In less industrialized, urbanized societies, there were stronger established community and, especially, family roles for elders. Today, one point of view is that society should try to restore the extended family and the “wise sage” role of the elderly. An alternative is that we make society relatively “ageless,” so that the elderly can be active participants who are neither especially revered nor isolated and put aside.

Some technologies may enable community integration even for those suffering from disabilities that have in the past increased isolation. Interactive communication technologies can keep people of all ages informed about what is happening in their communities. Virtual reality telecommunications in wide bandwidth can permit people to attend meetings and keep in touch with neighbors and family members when physical proximity is difficult to achieve. New transportation and personal mobility technologies may help many elderly get themselves physically, not just virtually, back into their communities.

Employment

If older citizens are to make continuing contributions to society, they must have opportunities to do so. This means that employers must value—and accommodate—older workers. (Their incentives to do so will increase with the labor shortages likely to appear as the post-war population bulge begins to retire.) Workplaces may have to become more flexible toward older workers (compensating measures for partially disabling conditions; tolerance for more part-time employment). Some combination of private and public sector institutions will need to provide opportunities for life-long learning and retraining to help older workers adapt to new industrial practices. In some cases, older volunteers receiving retirement pay may perform tasks now done by paid workers.

Several technologies could help workplaces adapt to older workers and vice-versa. We already have some adaptation of workplaces to make them accessible to disabled persons; older people with mobility problems could also benefit from these accommodations. Tools (in particular computers) can also be adapted to different users, for example those with reduced vision. For some, telecommuting may be effective, and the emergence of wide band communications will narrow the differences between being in the office and being at home.

If many millions of older workers are to keep pace with technology change, they will need continuing education and retraining. Distance learning and automated, but intelligent and adaptive, learning systems may be the only practical ways to provide so much education to so many.

Lifelong Contributions

Sunship Airlines has a large staff of aircraft maintenance personnel scattered all over the world. They have an aggressive multi-phased career program which looks like this:

- New workers serve as apprentices under experienced, older workers. Some of the training is hands on and some is "virtual." They have found that a large part of their success is tapping into the "empirical" knowledge of their older staff.
- As experienced staff age, they look forward to a distinguished, but physically less demanding, role in the apprentice program to help train new staff.
- Experienced, older staff are often called upon to help in the development of new processes and tools—working closely with the younger workers on bright new ideas.
- Most employees never "retire," but they are encouraged to work from home in many of the mentoring and consulting roles.

Health care

Changes in health care delivery institutions (we speak here mainly of the U.S. health care delivery system, with which we are most familiar) will be necessary if the aging population is to be kept healthier, longer, at less cost. Institutions will have to move away from a focus on episodic interventions in acute conditions and toward an integrated health care approach with a greater focus on prevention, forecasting, and early intervention. They will have to provide greater continuity of care for individuals across time and different providers. They will have to give more weight to outcomes research and evidence-based medicine in medical decision making. Physicians and other health care workers may become less omniscient and more like coaches and counselors who advise patients on making more of their own medical decisions. The institution of the general hospital may give way to specialized facilities (which nonetheless take a holistic approach to each patient).

Numerous technologies can enable the kinds of changes required. For example, health care institutions will have integrated information systems that give them access to life-long, portable, comprehensive health records for each patient. They may also use this data to carry out large population studies for assessing the most effective outcomes of medical practices. Patients may also have access to their own complete medical information, as well as to the best medical information about their own conditions. They may have personal

instrumentation systems for self- and remote health status monitoring, feedback on progress in life-style and health improvements, and reassurance about how they are faring.

Population Health and Public Policy

The many institutions involved in health, from governments to public health agencies to health care providers will have to learn to reduce the bifurcation between preservation and protection of population health on the one hand and medical intervention on the other. When it is done on a large enough scale, investment in preservation of community health has higher economic returns than investments in acute care.²

The most challenging task—and the one with the highest potential return—for those attempting an integrated approach to community health will be to learn how to persuade people to change their behaviors in health directions. Improving diet, exercise, and safety practices, while avoiding smoking and alcohol abuse, will be essential to maintaining the health of the elderly.

In addition, better understanding of the environmental factors in health (and how they relate to genetic dispositions) will be necessary. Further, since infectious diseases affect the elderly in disproportionate numbers, it will be important to strengthen public health infrastructure in general.

Coming information technology will enable integrated national (and international) public health information infrastructures. With the data that will become available from electronic medical records, along with advances in computer capacity and software development, public health entities should have computational tools that permit continuous analysis of public health status, of needs for public health interventions, and of results of interventions. They will be able to fuse non-medical (e.g. environmental) and medical data to better understand environmental health factors. Epidemiology will be faster and more comprehensive, and so, will enhance the ability to head off epidemics of infectious disease, as well as to assess the outcomes of public health and medical interventions.

Communications and computing technologies will also make it easier to educate people about the health risks of behaviors. Personal monitoring systems may give people personalized advice, feedback, and reinforcement. Better sensing technologies, cleaner manufacturing and transportation methods, and pollution-prevention techniques will contribute to reducing environmental risk factors.

² See Stephen Shortell (ed.), *Remaking Health Care in America* (San Francisco: Jossey-Bass, 2000).

The Health Coach

Jim, 65, quit smoking 6 months ago—with a little help from his electronic friends. When he visited his doctor 8 months ago, he signed up for a PHC—a personal health coach—that he consulted from time to time as he was watching TV. An artificial intelligence module in the PHC analyzed Jim's complete medical records (which are instantly available in electronic form).

Based on analysis of anonymous information from millions of others in the electronic medical records system, scientists have vastly improved their understanding of the factors that make the difference between health and disease. Drawing on this body of knowledge, Jim's PHC formulated a highly personalized profile of Jim's health status and of the things he needs to do to stay healthy.

That Jim should, among other things, stop smoking was obvious for the PHC and for Jim. But the PHC gave him detailed comparisons of the expected life and health spans of people who smoked and who also had Jim's current physical condition and genetic make-up. The prognosis was startling and persuasive: He had an 80% probability of heart disease in the next five years if he did not stop now.

Jim got a new exercise bike that linked to his PHC. Sensors on the bike told the PHC how his heart, lungs, and muscles were performing. The PHC gave Jim regular feedback on exactly what his exercise regimen should be. Just as important, it gave him regular feedback on his progress. Moreover, since Jim's health insurance program offered him a rebate for sticking to the no smoking and exercise program, he was making money!

Personal and Social Futures

Thus far we have discussed relatively high-level, society-wide issues. Here we focus in on the experiences of the individuals within society.

Self and role

If “society” expects individuals to make life-long contributions, individuals will have to embrace this new (for many) role. It will be difficult to keep people healthy and productive if they have not consciously chosen to be that way. They will have to get used to the ideas that they can keep learning in “old” age and that they can adapt to new working circumstances.

As noted above, the cultural and institutional environments of the elderly will have to adjust to *permit* them to keep participating in the economy. It seems likely that if society accepts their participation, and if they feel physically and mentally capable of it, they are likely to want it. (On the other hand, if work is painful and unsatisfying, just like their younger counterparts, the elderly will *not* want to do it.)

People who have reached the point of being unable to work still value a sense of independence and choice in life. Many would rather remain in their family homes, or

at least live in facilities where they have some independence, than live under the constant care of others. (Note that society also has an interest in their maintaining independence, since high levels of care are labor-intensive and expensive.)

The technology enablers for people adopting the new paradigm of life-long contribution are really those things that keep them feeling empowered: technologies that help maintain health and vigor (discussed above and below), assistive technologies that enhance mobility and strength (robotic devices or vision enhancers, for example), those that help them stay in communication with the mainstream of society, and those that help them continue to learn and grow mentally and spiritually.

Relation to family and community

People who want to be involved in work are also likely to want to be involved with family and community, to be a part of civic, neighborhood, family, and recreational activities. Again, technologies that help them feel healthy and enabled will encourage participation in family and community as well as work. In particular, user-friendly, high bandwidth communications technologies will help overcome not only mobility problems, but also the problems of distance and travel time in modern society.

Maintaining Connections

Anna is 95 years old and lives alone in Phoenix in a very "connected" home. She uses her "Doc -In-A-Box" for health advice and she is visited regularly by local friends. However, Anna has a special role. She supervises the activities of her great - great grandson, Dave, age 8, as he comes home from school in Portland, each afternoon until his parents return from work. When Dave pushes the front door bell in Portland, it rings on Anna's TV computer in Phoenix and a "picture-in-picture" image of the front door appears on her screen. Anna remotely controls the locks on the doors, and lets Dave in. She also controls the appliances in the house and starts the microwave heating the mini-pizzas that Dave really likes. She can control "ROBIE," a small robotic dog that plays with Dave but also acts as Anna's "eyes" as Dave roams through the house. Anna helps Dave with his homework and watches over him as he practices batting in the back yard. Sometimes they enjoy a "virtual snack time" together when Anna gets to tell Dave some of the stories from her past and Dave tells Anna about his friends at school.

Anna has major back problems, so she no longer drives and has many small robotic devices in her home that help to accomplish the housework. She does not go out often, but when she does, she uses the shuttle system for her neighborhood. This runs in a loop through the neighborhood, stops just outside her door every 15 minutes, and offers her access to the hairdresser and the grocery store. It also has a transfer to the larger transit systems for access to the hospital and the airport.

Health care environment

Integrated health care systems aimed at maintaining health and preventing disease must begin with individuals. We are already seeing signs of individuals taking more responsibility for their own health care decisions by gathering information on the internet about medical issues to discuss with their doctors. We also envision people receiving personalized information relating to their own health risks and behaviors, allowing them to take preventive steps even before medical consultations become necessary. Individuals (or, where appropriate, their families) will need education to take greater personal responsibility for their own health.

There are clearly important connections between mental and physical health. We know that physical exercise is important to maintaining both. There is some evidence that continued mental stimulation and activity are important to maintaining cognitive capabilities. Continued involvement in the larger community is one means by which people can remain mentally active. Thus the relationships of the person with other parts of the community than those specifically designated as “medical” are also part of the “health care environment” for that person.

A New Health Care Environment

June is a 75-year-old widow who lives alone in a "smart" home. Her appliances, including her medication dispenser and many health sensors, some that she wears as part of her jewelry, some that are implanted and some that are located in her bathroom, are all networked. These send data to "Doc-In-a-Box," her network-based "virtual doc," which presents information to her through her TV set. Each morning, "Doc B" comes on the screen and reassures her that everything is OK. "Doc B" also retains the data in a server and analyzes variances in her vital signs and blood chemistry on day-to-day, week-to-week, and month-to-month intervals.

Each morning, June turns on her TV (using her remote control which simultaneously measures her vital signs and does a complete non-invasive blood chemistry) to check the local weather, local news, the status of her investments, her family news and her personal health report from "Doc B." It reports to her the status of her major health concerns (arthritis and high blood pressure), reminds her of her status on the diet she is attempting to follow, reminds her of her status of her medications for the day, and alerts her to any unusual health events.

Today, "Doc B" tells her that her blood pressure has been elevated for a long enough time that an appointment has been made with her human doctor. An email message has been sent to her children (at her request) informing them of her change in status and the upcoming appointment. "Doc B" has also sent all of her health info since her last office visit to her blood pressure specialist.

Several technologies can empower people to make better personal health decisions. Ready electronic availability of personal health records will make it possible not only for individuals to understand their own health situations better, but for automated systems to give them personally adapted information and advice on

how to preserve health and manage diseases. Personal monitoring devices could provide people with feedback on their own status and progress, and also permit their health care professionals to do remote monitoring, diagnosis, and prescription. Telemedicine could save the individual time and money, as well as help society make more efficient use of scarce specialized health resources.

The Human Organism

As important as it will be to pursue community health policies that help more of the population stay healthy longer, people will still get sick. There is broad support in the United States for increasing the medical research budget of the National Institutes of Health to about \$27 billion per year by 2003. The National Institute on Aging will focus on research related to a range of geriatric disorders listed below:

- Alzheimer's disease and other degenerative diseases of the nervous system, and age-related changes in memory;
- major geriatric concerns, including weakness and falls, delirium, urinary incontinence, sleep disturbances, depression, and comorbidities;
- cardiovascular disease;
- cancer;
- diabetes;
- bone, muscle, skin, joint and movement disorders;
- vision, hearing and other sensory disorders;
- benign prostatic hyperplasia; and
- infectious diseases.³

There are clearly important social, educational, behavioral, and public health variables related to these conditions. But biomedical science will still have much to say about whether the diseases can be prevented or ameliorated.

Medicine has the potential to be a two-edged sword with respect to reducing the burdens to society of a large elderly population. New pharmaceuticals and other therapies can be very expensive, adding to total medical costs. Marginal benefits to society (and even to individuals receiving therapies) can greatly exceed marginal costs.

Discussions of medicine in relation to aging frequently center on whether and how medicine can enable people to live longer. From the societal point of view, longer life spans could exacerbate the aging population problem by further increasing the dependency ratio. The crucial objective, therefore, is to increase *quality-adjusted* life span—to compression of morbidity. That is, it is just as important to increase the healthiness of the last years of life as it is to increase their numbers. The ideal condition is that in which the amount of time one spends sick and disabled before dying should be very short. In addition, it would be desirable to have better prognostics, so that people avoid costly but ultimately futile medical therapies that have little chance of restoring health or relieving suffering.

³ See NIA *Strategic Plan FY 2001-2005* at <http://www.nih.gov/nia/strat-plan/2001-2005/>.

Prognostics

Arnie is 93 years old and has been struggling with a bad heart valve for years now. He has been lucky to be one of the first users of the "Virtual Body" which is an individualized model of his body. It has allowed very accurate predictions about the results of various proposed interventions. However, interventions are becoming less and less effective as more of the body seems to be weakening. Yesterday, Arnie's "Doc-in-a-Box" informed him that the prospects are very poor, and his physician is running the last simulations on his Virtual Body to see if any of the latest interventions might be successful. Today, his physician has told Arnie and his family that none of the simulated interventions were successful. The predictions are that Arnie will live from 1 week to 3 months. Arnie and his children begin preparing for the end.

We observe that biomedical science seems on the verge of revolutionary developments in the understanding of health and disease. The cataloging of the human genome, along with the exploration of gene expression, combined with detailed medical information about large numbers of people, will lead to unprecedented understanding of the implications of the interplay of genes, environment, and behavior for human health. Scientists will gain detailed knowledge of disease mechanisms and potential interventions. Biomedical science will depend on the rapid advances in the technologies of biological research, including advanced sensors, micromechanical instruments, and supercomputer modeling capabilities.

As noted above, advances in medical science and technology can lead to better, but more expensive, treatments for acute conditions. But they may also lead to new diagnostic techniques and preventative interventions that head off chronic or acute diseases before they result in costly care and treatment. Restorative or reconstructive interventions will enable people to function well enough to continue to be contributing members of society instead of becoming infirm dependents. Pharmaceutical alternatives to surgery, or less invasive surgeries, could also reduce the costs of hospitalization and recuperative down time.

The advances in biomedical science described above seem likely to lead to medical technologies enabling the kinds medical interventions just mentioned. Such technologies might include:

- gene chips for individual genetic profiling;
- gene therapies to correct cellular protein production malfunctions;
- much larger variety of drugs, "rationally designed," based on understanding of protein targets;
- "designer" pharmaceuticals, adapted to the individual's genome for effectiveness and absence of side-effects;
- inexpensive biosensors (portable or implantable) for early disease detection;
- genetic screening for specific vulnerabilities;
- immunotherapies that enhance the body's immune system and correct immunological deficiencies;
- superior, genetically targeted vaccination against infectious diseases;

- genetically targeted antibiotics answering the problem of antibiotic-resistant pathogens
- precision-delivered pharmaceuticals (via nanotechnologies)
- advanced prosthetic devices and tissue and organ growth and replacement therapies that obviate prostheses; and
- performance-enhancing drugs (e.g. for treating memory loss).

Advances in Medical Science

Janice, 71, an ex-accountant living in Denver, noticed the first signs of Alzheimer's Disease a few years ago and confirmed that she had a propensity for the affliction with the disposable "Genome-at-Home" test kit. In her "retirement," she has been teaching algebra via her home cable TV transmitter/receiver to 9th graders on the Navajo Reservation in Crownpoint, NM. They couldn't find a teacher who wanted to live out there, and so advertised for one on the web.

Lately, her students have mentioned to her that she seems to be forgetting what she has assigned for homework. She got really nervous when she couldn't remember one of her student's names. Janice logged onto her neural specialist physician's web site with her concerns. With 196 genes affecting Alzheimer's, she needed more specific testing than could be accomplished with her "Doc-in-a-Box" home health system.

Her human doctor had her come in for an analysis on what Janice affectionately calls the NAG (Nanotech Appliance for Good health) which identified an imbalance of 23 proteins. That info was sent over a secure web line to Janice's "Doc-in-a-Box," which analyzed the results against her present medication and sent a request to MyDrug.Com, a personalized drug creation and fabrication company. Two days later, a new "prescription cocktail" of protein-enhancer drugs, never before assembled for human consumption, was delivered to Janice. Within two days, she was back to normal, preparing her students for an exam.

Conclusions

The aging of their populations poses daunting challenges to the industrialized states. If we do not anticipate and deal with these issues, the rising ratios of traditionally dependent elderly to those of traditionally working would seem likely to impose severe taxation burdens on workers, make it impossible for governments to meet their prior pension and health care benefit commitments, strain health care systems, and force a low quality of life on many elderly. In addition, governments would find it more difficult to meet national security and other public good requirements, while industries would be starved for workers.

The worst forecasts along these lines assume that the projected dependency ratios are an inevitable result of the age profiles of populations. We argue that this assumption results from holding technology constant, and assuming that nothing will happen to enable many of the elderly to continue to be productive, healthy, independent contributors to society. We have indicated that many promising advances in technology—if combined with appropriate changes in cultural expectations and societal behavior—can falsify that assumption. Nevertheless, the necessary combinations of technology and social change will probably not occur spontaneously. National research investment policies and enlightened leadership into this demographically new world will be needed, if we are to make the dramatic improvements that are certainly possible.